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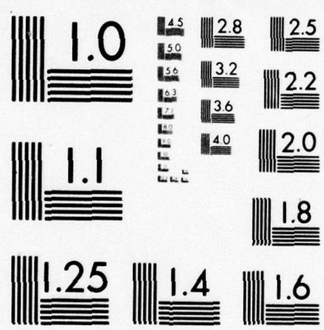

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(6) CLASSIFICATION LISTS
A Useful Way to Organize Ship Design Data

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Classification Lists

A Useful Way to Organize Ship Design Data

Abstract

This paper introduces a method of organizing ship design data that is significantly different from existing approaches. This new method of data organization allows data classification systems to be expanded to meet new demands, while at the same time retaining the constancy necessary to keep old data from becoming obsolete. In addition, it allows different engineers to view the same data different ways to meet their own needs.

The net result can be reduced cost to the design agency, as data classification systems using this approach will stand the test of time longer. Also, improvement in the ship design process can be expected as the greater flexibility of this approach will allow engineers to do their jobs more effectively.

Introduction

This paper presents a method of data classification that combines the features of several traditional methods, but does so in a new way. The result is a set of very desirable and powerful features. However, the technique is cumbersome when carried out by hand, which perhaps explains why it was discovered recently as part of a computer-aided design research project, and not earlier.

Related to this fact is another which is worth mentioning, namely - computers are changing, and will continue to change, the way we do design. This is true not only because machines are fast, but also because methods which worked well by hand do not always work well on computers. Conversely, methods well suited to computers are not always convenient when carried out manually.

This is one such method.

General

The Classification List approach to data classification is not a single technique, but is composed of several closely interwoven techniques. Therefore, to understand the Classification List approach requires an understanding of the several entities which are its constituent parts. These include:

1. Organizational Systems
2. Classification Lists
3. System Correlation Matrices
4. List Correlations
5. Related Classification Lists
6. Classification Attributes

Each of these entities will be described separately. First, however, we will discuss why we bother with data classification at all.

Why Classify?

The purpose of any data classification scheme is to answer questions not easily answered otherwise, the most common being - "what, where, why, and what kind."

"What" data is this? Data classification schemes answer this question by specifying a breakdown for design data. This divides a large amount of data into a set of more easily managed pieces.

"Where" can this data be found? Careful construction of the organizational aspects of the classification scheme allow any piece of data to be easily located when needed.

"Why" is this data necessary? A data classification scheme can give insight into why a piece of data is present by specifying its function, or operational contribution to the design.

"What kind" of data is this? This question can be addressed by having a classification scheme specify a data item's "type," or method of operation within the design.

Classification schemes are also useful for answering questions regarding data interrelationships. This can be accomplished by providing data subtotalling capability, and also by use of various types of data correlations.

Note that the above questions are not readily answered by use of data values; the answers are qualitative rather than quantitative in nature. For example, the weight of a data item is readily described by a number such as 100 (100 tons, kilograms, etc.). However, to say the same data item has a function of 100 is meaningless, unless it is given meaning by a data classification scheme. If a given classification scheme defines 100 as Hull Structure, then a "function value" of 100 becomes meaningful. Thus, data classification provides a vehicle by which qualitative information may be described in a quantitative manner.

On the other hand, it is generally not efficient to use data classification schemes to answer questions that are quantitative in nature, as these are more readily answered by data values.

Organizational Systems

One very common way of building a classification scheme is to use a hierarchal, or "tree," structure as the basic format. As applied in the Classification List approach, hierarchal structures are composed of the following three elements.

1. I.D. Label - an alphanumeric string of characters that serves as the name of the given line.

2. Description - a short (one line) definition of the given line.

3. Level Number - an integer value that defines the ranking of the given line within the hierarchal structure. Higher level numbers imply greater levels of breakdown, i.e., finer branches of the tree. The first line must have a Level Number of zero, i.e., the "trunk" of the tree.

Figures 1a and 1b illustrate how these elements combine to form hierarchal structures.

Figure 1a

Sample Hierarchal Structure
Navy Ship Work Breakdown Structure (SWBS)
Group 300 (partial)

I.D. Label	Description	Level Number
SYS	Shipboard Requirements	0
300	Electric Plant	1
310	Electric Power Generation	2
311	Ship Service Generators	3 *
312	Emergency Generators	3 *
313	Batteries	3 *
314	Power Conversion Equip.	3 *
340	Power Generation Support	2
341	SSTG Lube Oil Sys.	3 *
342	Diesel Support Sys.	3 *
343	Turbine Support Sys.	3 *

* Lowest levels

Figure 1b

Sample Hierarchal Structure
Bureau of Ships Consolidated Index (BSCI)
Group 3 (partial)

I.D. Label	Description	Level Number
SYS	Shipboard Systems	0
3	Electric Plant	1
300	Electric Power Generation	2 *
301	Power Distribution Switchboards	2 *
302	Power Distribution Sys. (Cable)	2 *

* Lowest levels

All hierarchal structures may be broken into two parts - an independent part and a dependent part. The Level Numbers may be used to distinguish the two parts as follows:

If the Level Number of a given line is greater than or equal to the Level Number of the next line, the given line belongs to the independent part of the system.

The independent lines are referred to as "lowest levels", whereas the dependent lines are called "upper levels". Data values for upper levels are obtained by summing lowest level values. Therefore, data values only need be obtained for the lowest levels to define values for the entire system. In summary, then, the lowest levels define the basic definition of the scheme, while upper levels supply sub-totalling capability and systematic organization via hierarcal structure. For this reason, we shall refer to hierarchal classification schemes as "Organizational Systems."

Classification Lists

Another way of building a classification scheme is to use a simple list structure as the basic format. A list structure is defined by specifying two types of elements.

1. I.D. Label - an alphanumeric string of characters that serves as the name of the given line.

2. Description - a short (one line) definition of the given line.

Figures 2 and 4 illustrate how these elements combine to form list structures.

Figure 2

Sample List Structure
Requirements Classification List (REQ)

I.D. Label	Description
300A	Ship Service Generators
300B	Emergency Generators
300C	Battery Charging Equip.
300D	Power Conversion Equipment
300E	SSTG Lube Oil System
300F	Diesel Generator Support Sys.
300G	Turbine Generator Support Sys.

In many respects, a list structure is equivalent to the lowest levels of an Organizational System listed both without Level Numbers and in any arbitrary order. All organizational and subtotalling characteristics of the Organizational System have been stripped away, and only the basic definition of the classification scheme inherent in the lowest levels has been retained. This simple structure will be referred to as a "Classification List." Classification Lists are the heart of the Classification List approach to data classification.

System Correlation Matrices

One problem frequently encountered in design is that different engineers need to structure and subtotal the same basic data different ways. This frequently leads to a proliferation of Organizational Systems (engineers seem to prefer hierarchal structures), each tailored to a specific use, and all unreconcilable. Thus, data produced by one engineer in his system cannot readily be assimilated by other engineers into their systems. Any attempt to create a common Organizational System invariably leads to compromises which please few and anger many.

The Classification List approach offers a workable solution to this problem:

1. Instead of creating a common Organizational System, create a common Classification List. This defines the classification breakdown without specifying organizational or subtotalling characteristics.

2. Allow each engineer to create and use his own Organizational System and System Correlation Matrix.

The key to this solution is the System Correlation Matrix, which is simply a mapping between the common Classification List and the various Organizational Systems. It consists of (N + 1) elements, where (N) is the number of Organizational Systems, as follows:

1.) List I.D. Label - the I.D. Label of the given line of the Classification List.

2. - N.) System I.D. Labels - the I.D. Labels of the corresponding lines of each Organizational System.

Figure 3 illustrates a simple System Correlation Matrix composed of three elements (two Organizational Systems).

Figure 3

Sample
System Correlation Matrix

Classif. List (REQ) I.D. Label	Sys. #1 (SWBS) I.D. Label	Sys. #2 (BSCI) I.D. Label
300A	311	300
300B	312	300
300C	313	302
300D	314	300
300E	341	300
300F	342	300
300G	343	300

When building a System Correlation (one column of the Matrix), the following rules must be adhered to:

Rule #1. Each List I.D. may map into one, but only one, System I.D.

Rule #2. Each System I.D. must map into one, and only one, List I.D.

Rule #3. System I.D.s may be either upper or lower levels of the System.

Rule #4. A List I.D. need not map into any System I.D.

Some of the implications of these rules are as follows:

1. A System may address a subset of the total classification breakdown of the List (Rule #4).

2. A System may not contain less breakdown than the subset of the List which it addresses (Rule #2).

3. A System may contain more breakdown than the List, but only if the extra breakdown occurs below upper levels which themselves map directly into the List (Rules #1 and #3).

Notice that in Figure 3 System #2 violates Rule #2. This is an example of an invalid System; data developed using System #2 cannot be transformed into either the Classification List or System #1. However, data developed using System #1 (a valid system) may be transformed into either the List or System #2. This demonstrates the reason for the above rules. Also, notice that System #2 is valid for subtotalling, even though it is invalid for data development. In general, if a System is to be used only for subtotalling, and not data development, Rule #2 may be waived.

Thus, it is indeed possible for engineers to use their classification schemes and still be able to communicate. All that is required is a common communication medium (a Classification List) and the discipline to interface with it (Rules #1 to #4).

List Correlations

System Correlation Matrices provide a mechanism for restructuring a common classification breakdown. Frequently, however, it becomes necessary to relate fundamentally different breakdowns, each represented by a separate Classification List. For example, Figure 4 depicts a compartment-oriented List that is fundamentally different from the hardware-oriented List of Figure 2.

Figure 4

Sample List Structure
Ship Space Classification List (SSCL)

I.D. Label	Description
3.21	Engine Room
3.22	Auxiliary Machinery Room
3.41	Ship Service Generator Room
3.42	Emergency Generator Room
3.51	Diesel Oil Tank
3.52	JP-5 Tank
3.53	Lube Oil Tank
3.61	Intake Trunk
3.62	Exhaust Trunk

Such different Classification Lists may be related by creating a List Correlation of two elements, as follows.

1 and 2). List I.D. Labels - the I.D. Labels of related lines of the Classification Lists.

Figure 5 is one possible List Correlation between the Lists of Figures 2 and 4. In this case, hardware is being mapped into various compartments, an operation critical to many design tasks, such as arrangements, weight and centers estimating, distributive system routing, and vulnerability analysis.

Figure 5

Sample List Correlation

List Correlation

Description	I.D. Label (REQ)	I.D. Label (SSCL)	Description
S.S Generators	300A	3.41	S.S Generator Rm.
Emer. Generators	300B	3.42	Emer. Generator Rm.
Battery Charging	300C	3.22	Aux. Machy. Rm.
Power Conversion	300D	3.22	Aux. Machy. Rm.
SSTG L.O. Sys.	300E	3.41	S.S. Generator Rm.
SSTG L.O. Sys.	300E	3.53	L.O. Tank
Diesel Gen Support	300F	3.42	Emer. Generator Rm.
Diesel Gen Support	300F	3.51	Diesel Oil Tank
Diesel Gen Support	300F	3.61	Intake Trunk
Diesel Gen Support	300F	3.62	Exhaust Trunk
Turbine Gen Support	300G	3.41	S.S. Generator Rm.
Turbine Gen Support	300G	3.52	JP-5 Tank
Turbine Gen Support	300G	3.61	Intake Trunk
Turbine Gen Support	300G	3.62	Exhaust Trunk

Classification List for Hardware (REQ)

Classification List for Compartments (SSCL)

There is no theoretical restriction on building a List Correlation; I.D. Labels of one List may be mapped into as few or as many Labels of the other List as desired. In practice, however, restrictions or conventions may be established commensurate with the nature of the specific problem being addressed.

Related Classification Lists

One important aspect of design that influences the construction of Classification Lists is level of detail. In early design stages, the level of detail is gross, and corresponding Classification Lists will have relatively few lines. In later design stages, the level of detail becomes finer, and Classifiction Lists must grow in size to accommodate the additional classification breakdown. Thus, different Classification Lists are needed for different design stages. However, these different Lists must be coordinated such that later stage data can be mapped directly into earlier stage Lists for purposes such as monitoring space and weight growth. Similarly, data in one design stage must be capable of initiating the next design stage, i.e., the Classification Lists must be capable of "passing the design along." To meet these requirements, Related Classification Lists can be used.

Like System Correlation Matrices, Related Classifiction Lists relate data that is fundamentally the same, but use List Correlations to do so. Also, in this case, a set of Rules must be followed when creating the List Correlations.

Rule #1. Each List I.D. of the later stage system must map into one, and only one, early stage List I.D.

Rule #2. Each early stage List I.D. must map into one or more later stage List I.D.s.

These rules imply that a later stage Classification List must be created directly from an earlier stage List by further breaking down individual lines of the early stage List (Rule #2). Lines resulting from the further breakdown may not be recombined with one another (Rule #1).

There are no restrictions on Organizational Systems associated with Related Classification Lists beyond the Rules relating to System Correlation Matrices; each List may have its own unique set of Organizational Systems. Therefore, early stage and later stage engineers may organize the design data differently to suit their own needs.

Figure 6 illustrates Related Classification Lists for both an earlier and a later design stage than the List of Figure 2.

Figure 6

Related Classification Lists

Later Stage Classification List		See Figure 2 for Classification List	Earlier Stage Classification List	
Description	I.D. Label (REQ +)	I.D. Label (REQ)	I.D. Label (REQ -)	Description
SSTG Generators	300A1	300A	3001	Ship Serv. Power Gener.
S.S. Diesel Generators	300A2			
S.S. Gas Turbine Gen.	300A3			
AC-DC Rectifiers	300D1	300D		
60-400 Hz Freq Convert.	300D2			
Diesel Emer. Generators	300B1	300B	3002	Emer. Power Gener.
Gas Turb Emer. Gener.	300B2			
Battery Charging	300C1	300C	3003	Power Gener. Support
SSTG L.O. Sys.	300E1	300E		
Diesel Gen. Fuel Sys.	300F1			
Diesel Gen. L.O. Sys.	300F2			
Gas Turb. Fuel Sys.	300G1	300G		
Gas Turb. L.O. Sys.	300G2			

List Correlations

Classification Attributes

Thus far, methods have been presented for answering both the "What", or specification of breakdown, question (i.e., use Classification Lists) and also the "Where," or specification of organization, question (i.e., use Organizational Systems). In addition, methods of inter-relating data using both subtotalling (via Organizational Systems) and correlations (System Correlation Matrices, List Correlations, and Related Classification Lists) have been presented. However, two questions still remain unanswered - "Why" or specification of function, and "What Kind," or specification of type. Both of these questions are directly addressed by the breakdown inherent in a Classification List. The answers a Classification List is capable of providing to the "Why" and "What Kind" question are called the Classification Attributes of the List.

Classification Attributes are extremely important because they form the building blocks from which a Classification List is built. There are two basic kinds of Classification Attributes: Function Attributes, which address the "Why" question, and Type Attributes, which address the "What Kind" question. A Classification List may be built from Function Attributes, or Type Attributes, or both.

Function Attributes attempt to explain why something is needed, usually by specifying its operational contribution to the design. Also, Function Attributes tend to be insensitive to time and technological change, so a Classification List built largely from Function Attributes could be used for a long period of time with relatively few modifications.

Figure 7 gives an example of Function Attributes.

Figure 7

Function Classification Attributes

Function

I.D. Character	Name	Definition
E	Power Generation	Generation and control of power required for the operation of onboard equipment and machinery
P	Propulsion	Generation and harnessing of power required for locomotion of the ship

Sub-Function

I.D. Character	Name	Definition
O	Operation	Performance of the primary tasks or duties involved in carrying out the given Function
S	Support	Generation and/or control of factors required for the proper performance of the given function

Type Attributes are used to specify qualities that are important to the design. Frequently, this takes the form of specifying method of operation, or the various ways of achieving a function. Consequently, Type Attributes frequently act as modifiers to Function Attributes, but unlike Function Attributes, Type Attributes tend to be time and technology dependent. Thus, a Classification List built largely from Type Attributes will probably require frequent modification to remain current.

Figure 8 shows some sample Type Attributes.

Figure 8

Type Classification Attributes

Operating Condition

I.D. Character	Name	Definition
S	Ship Service	Equipment used to carry out a given Function under normal operating conditions.
E	Emergency	Equipment used to carry out a given Function when the Ship Service equipment is damaged or otherwise unavailable.

Type of Prime Mover

I.D. Character	Name	Definition
S	Steam Turbine	Steam turbines and their associated boilers that provide the primary source of power for carrying out a given Function.
D	Diesel	Diesel internal combustion engines that provide the primary source of power for carrying out a given Function.
G	Gas Turbine	Gas turbine engines that provide the primary source of power for carrying out a given Function.

Figure 8 (Continued)

Type of Support System

I.D. Character	Name	Definition
F	Fuel	Systems for storing, treating, and transporting the reactant agent for prime movers that harness chemical energy
A	Air	Systems for storing, treating, and transporting the oxidizing agent for prime movers that harness chemical energy
L	Lube Oil	Systems for storing, treating, and transporting lubricants for prime movers. Does not include systems dedicated to the lubrication of prime mover support systems (goes with support system)

The first step in building a Classification List is to determine the Classification Attributes, which consists of defining the following three elements.

1. I.D. Character - a one character identifier representing the given Attribute.

2. Name - a one or two word description of the Attribute.

3. Definition - an explicit, unambiguous explanation that serves as the "rulebook" for determining whether the Attribute applies to a given piece of data.

Figures 7 and 8 also give examples of this structure.

The second step in building a Classification List is to combine the Classification Attributes to form the List. Although the Attributes could theoretically be combined in many ways, in practice, the person defining the Attributes will usually have done so with an eye toward how they will combine to form the List, so this step will probably be relatively straightforward.

Figure 9 shows one way of combining the Classification Attributes of Figures 7 and 8 into a Classification List.

Figure 9

Classification List
built from
Classification Attributes

Requirements Classification List, Structured (REQ-S)

I.D. Label	Description
EOSS	Ship Service Power Turbor-Generators
EOSD	Ship Service Power Diesel Generators
EOSG	Ship Service Power Gas Turbine Generators
EOES	Emergency Power Turbo-Generators
EOED	Emergency Power Diesel Generators
EOEG	Emergency Power Gas Turbine Generators
ESSSF	S.S. Turbo-Generators Fuel Sys.
ESSSA	S.S. Turbo-Generators Air Sys.
ESSSL	S.S. Turbo-Generator Lube Oil Sys.
ESSDF	S.S. Diesel Generator Fuel Sys.
ESSDA	S.S. Diesel Generator Air Sys.
ESSDL	S.S. Diesel Generator Lube Oil Sys.
ESSGF	S.S. Gas Turbine Fuel Sys.
ESSGA	S.S. Gas Turbine Air Sys.
ESSGL	S.S. Gas Turbine Lube Oil Sys.
ESESF	Emergency Turbo-Generator Fuel Sys.
ESESA	Emergency Turbo-Generator Air Sys.
ESESL	Emergency Turbo-Generator Lube Oil Sys.
ESEDF	Emergency Diesel Generator Fuel Sys.
ESEDA	Emergency Diesel Generator Air Sys.
ESEDL	Emergency Diesel Generator Lube Oil Sys.
ESEGF	Emergency Gas Turbine Generator Fuel Sys.
ESEGA	Emergency Gas Turbine Generator Air Sys.
ESEGL	Emergency Gas Turbine Lube Oil Sys.

Notice that the Classification List of Figure 9 answers all of the questions hinted at in the List of Figure 2. Figure 9 is much more complete and comprehensive than Figure 2, however, because it was developed from sets of Classification Attributes, each set completely addressing one type of question. Thus, Classification Attributes provide a structured, rational method for building a Classification List based on the questions it must answer. In addition, the Classification Attributes provide the definition of the Classification List via the Attribute "Definition" element; definitions need not be written for each line of the List itself. Modification of the List also becomes easier by use of the Attributes. If new questions need to be answered, one simply creates a new set of Classification Attributes, and combines these with the existing List to form a new List. The new and old Lists will be Related Classification Lists, and data in the new List will be directly mappable into the Old List. Also, data in the old List can be mapped into the new List if the data can be further broken down according to the new set of Attributes. Expansions to existing sets of Attributes, such as to update Type Attributes to reflect new technology, can be handled the same way.

The following summarizes the major points regarding the use of Classification Attributes.

1. Attributes should be chosen to answer questions involving function, type, or other issues of a qualitative nature.

2. Attributes should not address issues of a quantitative nature, such as size, location, strength, magnitude, direction, etc.

3. Only Attributes which are important to the design should be chosen.

4. Attributes may be used to modify other Attributes. "I.D. Characters" of modifying Attributes are combined to form Classification List "I.D. Labels." "Names" of modifying Attributes are combined to form Classification List "Descriptions." The definition of a line in a Classification List is provided by the "Definitions" of its constituent Classification Attributes.

5. Function Attributes should not be used to modify Type Attributes. All other modification possibilities are acceptable, e.g., Function modifying Function, Type modifying Type, Type modifying Function.

6. A new Classification List formed by expanding existing Attributes, or adding new sets of Attributes, to an existing List forms a Related Classification List with the existing one.

Real World Application

The following is an example of a recent application of the Classification List approach to solve a real world problem.

Several years ago, the Navy changed from the Bureau of Ships Consolidated Index (BSCI) classification system to the Ship Work Breakdown System (SWBS). As a result, it became necessary to convert much weight data collected and organized by BSCI to the new SWBS system.

This conversion process could be broken into three separate cases. The simplest case involved mapping a BSCI weight directly to a corresponding SWBS category.

Case 1: BSCI XXX → SWBS AAA

In other cases, several BSCI weights needed to be added to form a corresponding SWBS weight.

Case 2:
BSCI XXX ↘
BSCI YYY → SWBS AAA
BSCI ZZZ ↗

In most cases, however, part of several BSCI weights needed to be added to form a SWBS weight.

Case 3:
BSCI XXX → BSCI XXX1 → SWBS AAA
BSCI XXX → BSCI XXX2 → SWBS AAA
BSCI YYY → BSCI YYY1 → SWBS AAA
BSCI YYY → BSCI YYY2

Because most SWBS groups were formed as per Case 3, converting weight from BSCI to SWBS was a complex, confusing, and time-consuming task worthy of the time of the most experienced Navy weight engineers. In addition, SWBS weights could not be mapped back to BSCI without a similar effort, making it impractical to compare new SWBS weights against old but well-established BSCI data and algorithms when and if the need arose. Navy weight engineers were faced with a formidable problem.

A solution emerged in the form of the Classification List approach.

BSCI and SWBS were Organizational Systems of a similar nature (both classified hardware and requirements by function and type.) Two such Organizational Systems may be related by a System Correlation Matrix of three elements:

Element 1 - Classification List I.D. Label
Element 2 - SWBS I.D. Label
Element 3 - BSCI I.D. Label

Two of these three elements, i.e., BSCI and SWBS Labels, were already defined. Thus the Classification List was the only missing element.

The required Classification List was formed as follows:

1. All BSCI Lowest Level I.D. Labels were listed.

2. Each I.D. Label in the list was identified as belonging to Cases 1, 2, or 3.

3. All I.D. Labels identified as case 1 or 2 were retained as is.

4. All I.D. Labels identified as Case 3 were broken into the parts necessary to map into SWBS. These parts were added to the list, and the original I.D. Labels from which they were derived were discarded.

With the Classification List thus formed, the System Correlation Matrix was easily developed.

This Classification List and System Correlation Matrix provided the following new capabilities.

1. Weights classified using the Classification List could be readily summarized by both BSCI and SWBS via the Correlation Matrix.

2. The Classification List served as explicit documentation of the BSCI to SWBS conversion process, with the following effects.

   a. The probability of error in the conversion process was reduced.

   b. The conversion task became easier to contract out.

   c. The cost of conversion was reduced.

3. Weights classified using the Classification List became relatively insulated from periodic changes made to SWBS. Many such changes were handled by simply changing the SWBS Correlation Matrix, with few or no modifications needed in the library of weight data already converted to Classification List format.

A further point worth mentioning is that this real world problem was solved using only three of the six parts of the full Classification List approach:

1. Organizational Systems
2. Classification Lists
3. System Correlation Matrices

List Correlations, Related Classification Lists, and Classification Attributes were not invoked in this particular case. Thus, the Classification List approach provides engineers and designers with a workshop of half a dozen tools, any or all of which may be used to build a solution to data classification problems.

Conclusion

This paper has described Classification Lists - how to build them, relate them, and organize and subtotal them different ways. But, because of the versatile and dynamic nature of the Lists, this paper does not claim to have touched on all their possibilities. If you have a data Classification problem that is not addressed by this paper, it is still extremely probable that the Classification List approach can provide the answer - either by inventing a new kind of correlation or, perhaps, by some other mechanism or relationship not even envisioned as of this writing. The possibilities are limited only by one's imagination.

BIOGRAPHY

Mr. Lutowski graduated with a B.S. in naval architecture and marine engineering from the University of Michigan in 1970, and has a M.S. in Ocean Engineering from Stevens Institute of Technology. He has worked in the Advanced Technology Branch of the Naval Ship Engineering Center as a naval architect for the past seven years. During this period of time, he has served as a specialist in applying computers to the Naval ship design process.